

Development of a Tropical Cyclone Tornado Parameter (TCTP) for use in situational awareness forecasting

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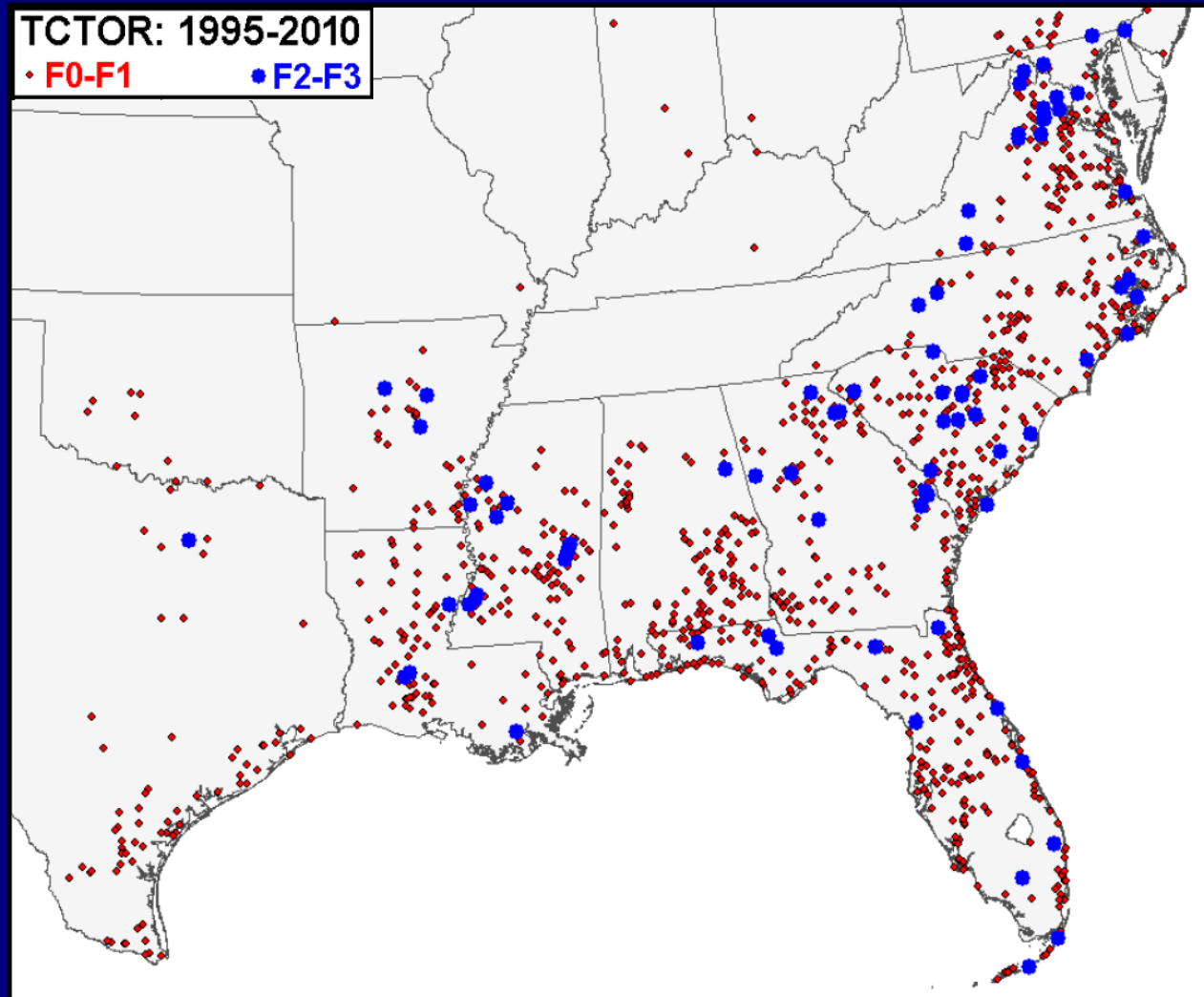
and

**Chris Link
Brian Hays**

Motivation – TC Tornado Climatology

Edwards (2012):

- Review of TC Tornadoes (1995-2010: WSR-88D era)
- U.S. Total: 1163
 - 6% of all events
 - Average 35 per TC
 - 118 in Ivan (2004)
 - \$1.4 billion damage
 - 43 deaths
- Carolina total: 176
 - ~20% of all events
 - 2004-2005 seasons
- Most are weak (EF0/EF1)
- Short lived (< 20 minutes)
- Afternoon / Evening events
- Spawned by “mini” supercells



From Edwards (2012)

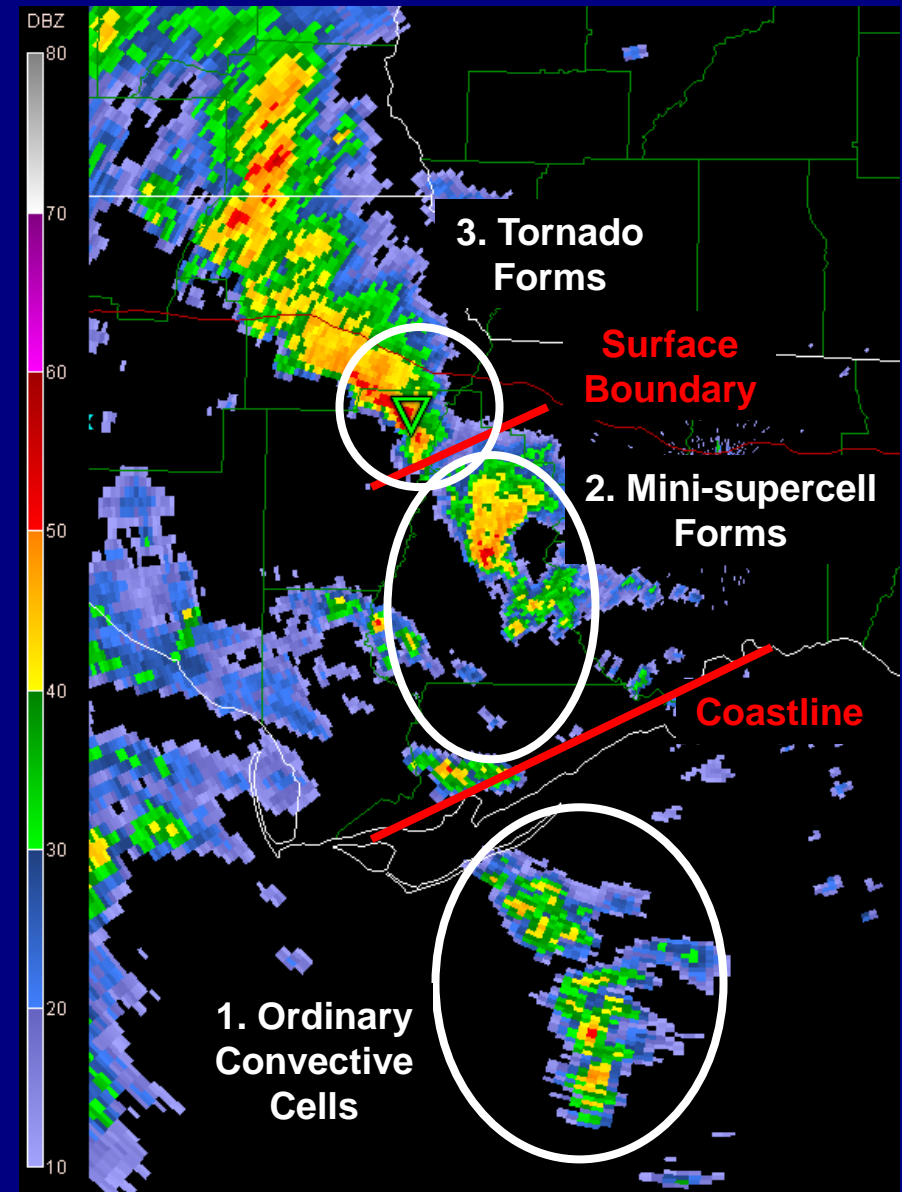
Motivation – TC Tornado Formation

Favorable Environment:

- Right-front (NE) quadrant
- Low LCL (< 500 m)
- Moderate CAPE (> 700 J/kg)
- Strong low-level shear (> 10 m/s lowest 1-3 km)
- Large low-level helicity (> 100 m²/s² in lowest 1-3 km)
- Midlevel dry air intrusion
- Low-level “boundary”
- Large SCP and STP (> 1)

Novlan and Gray (1974), Gentry (1983), McCaul (1991), McCaul and Weisman (1996), Spratt et al. (1997), Bogner et al. (2000), McCaul et al. (2004), Curtis (2004), Schneider and Sharp (2007), Baker et al. (2008), Eastin and Link (2009), Edwards (2010, 2012)

Conceptual Model:

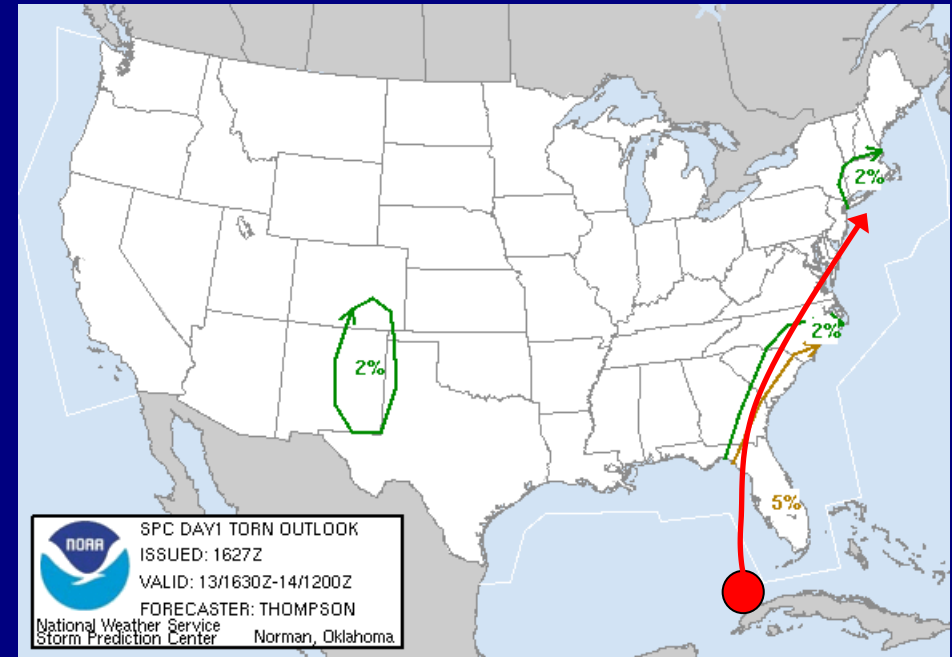


Motivation – TC Tornado Forecasting

Situational Awareness:

- **Multi-tool Approach**
- **Convective Outlooks (SPC)**
 - 1-3 days before landfall
 - Track Forecasts (NHC)
 - Path of Right-Front Quadrant
- **Watches (SPC)**
 - Hours before landfall
 - Objective Guidance
 - Models (WRF / GFS)
 - Indices (CAPE / SCP / STP)
 - Manual Analysis
- **Nowcasting / Warnings (SPC / WFOs)**
 - During landfall (and after)
 - Doppler Radar
 - Surface / Rawinsondes
 - Objective Guidance (RUC / Indices)

Example: TC Charley (2004)

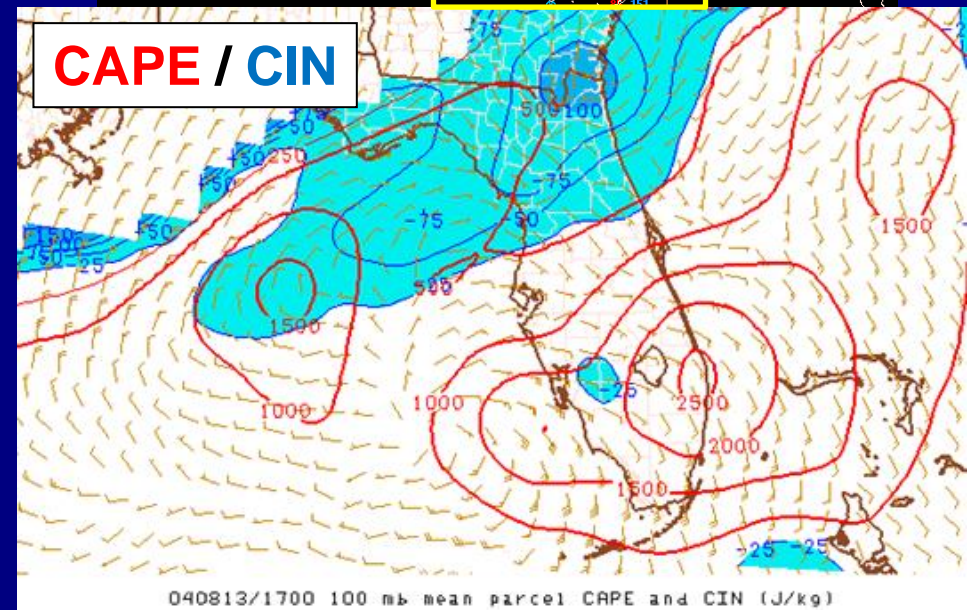
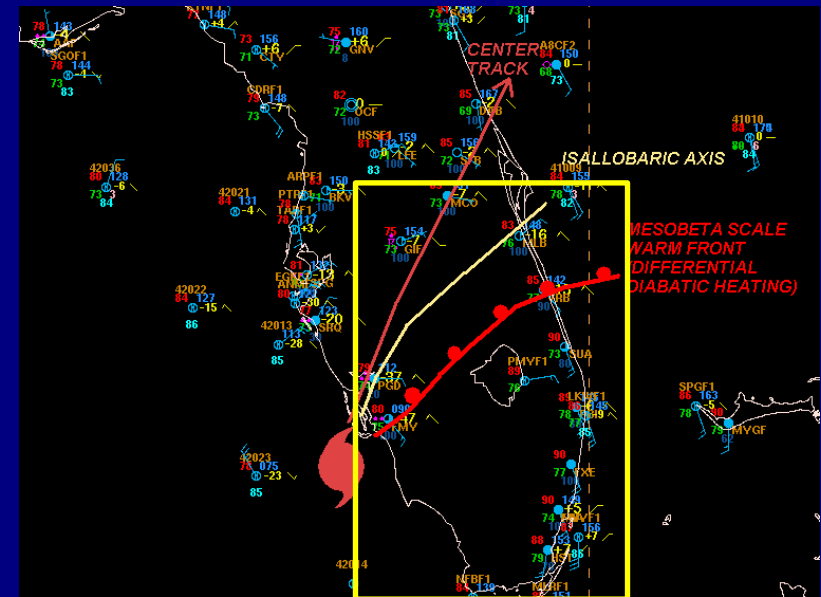


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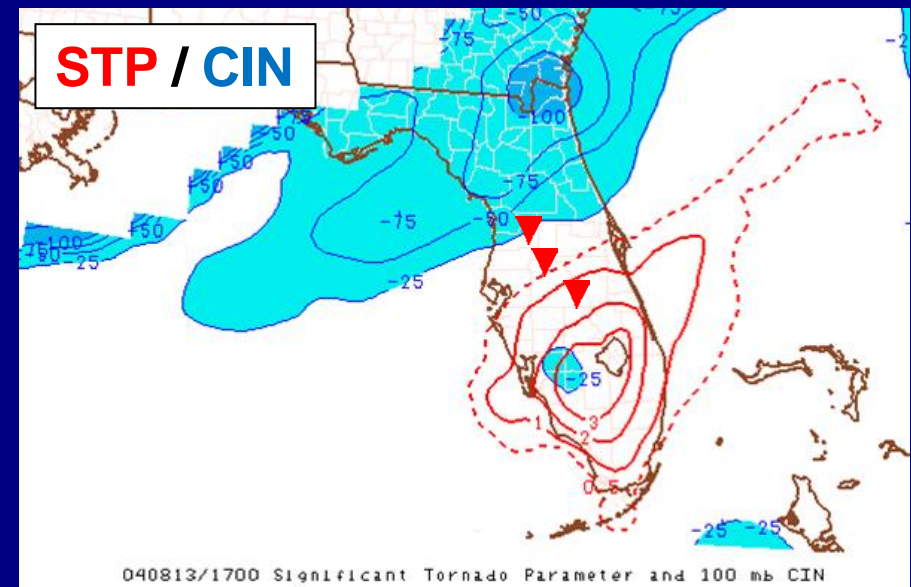
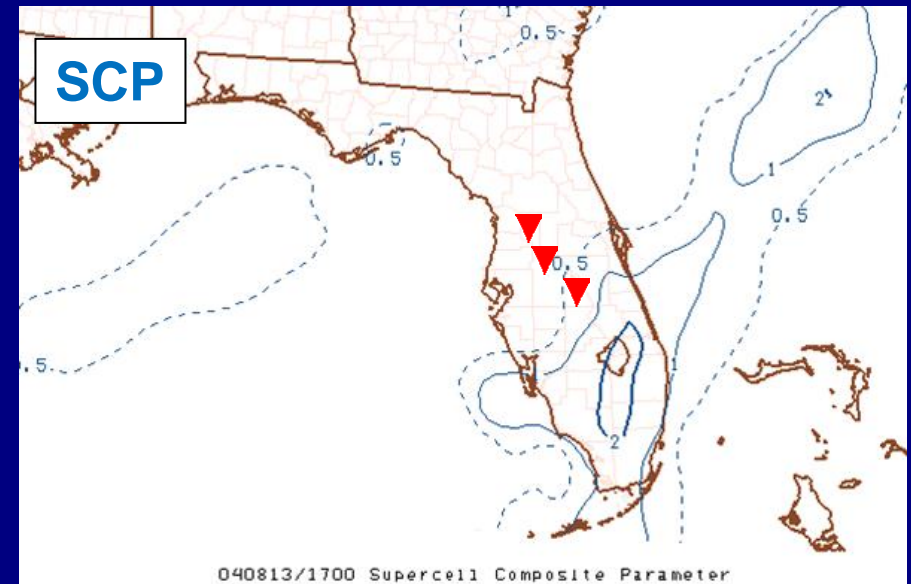


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 - **Surface / Rawinsondes (Indices)**
 - Objective Guidance (RUC / **Indices**)

Example: TC Charley (2004)



Motivation – Midlatitude Tornado Forecasting

Supercell Composite Parameter (SCP)

- Thompson et al (2003)
- Single normalized non-dimensional parameter
- Supercells → $SCP > 1.0$
- Developed from midlatitude supercell cases

$$SCP = \left(\frac{MUCAPE}{1000 J kg^{-1}} \right) \times \left(\frac{03CRH}{100 m^2 s^2} \right) \times \left(\frac{06SHR}{40 m^2 s^{-2}} \right)$$

Significant Tornado Parameter (STP)

- Thompson et al. (2003)
- Single normalized non-dimensional parameter
- Tornadoes → $STP > 1.0$
- Developed from midlatitude EF2-EF5 cases

$$STP = \left(\frac{MLCAPE}{1000 J kg^{-1}} \right) \times \left(\frac{01CRH}{100 m^2 s^2} \right) \times \left(\frac{06SHR}{20 m s^{-1}} \right) \times \left(\frac{2000 - MLLCL}{1500 m} \right)$$

Motivation – Miniature Supercells

TC Tornado Production:
(Edwards 2010)

85% supercells – discrete/cluster/lines

Size / Radar Limitations:

Must be close for radar detection

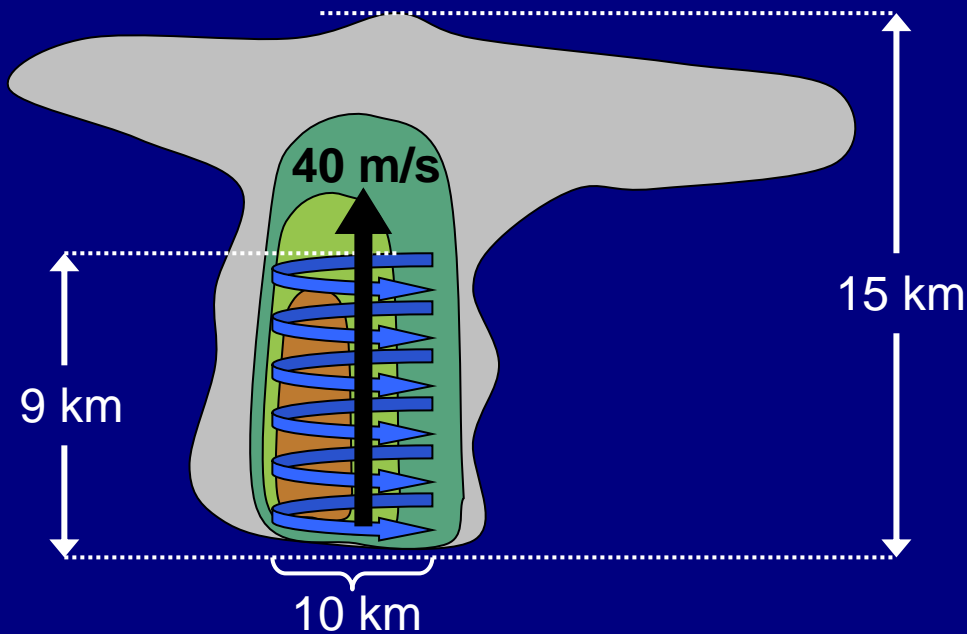
Duration:

Short - lived (< 30 min)

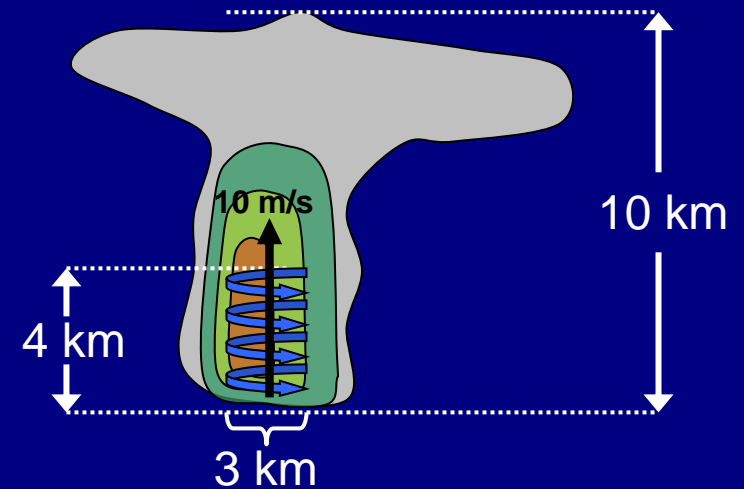
Forecast Methods:

Same as Midlatitude Supercells (SCP / STP)

Midlatitude Supercell



Miniature Supercell



Motivating Questions

1. How effective are SCP and STP at identifying “threat corridors” for *miniature* supercells and tornadoes within landfalling TCs?
2. Can an *improved index* be developed that better incorporates the relevant physical processes consistent with the diminutive size of supercells in the TC environment?

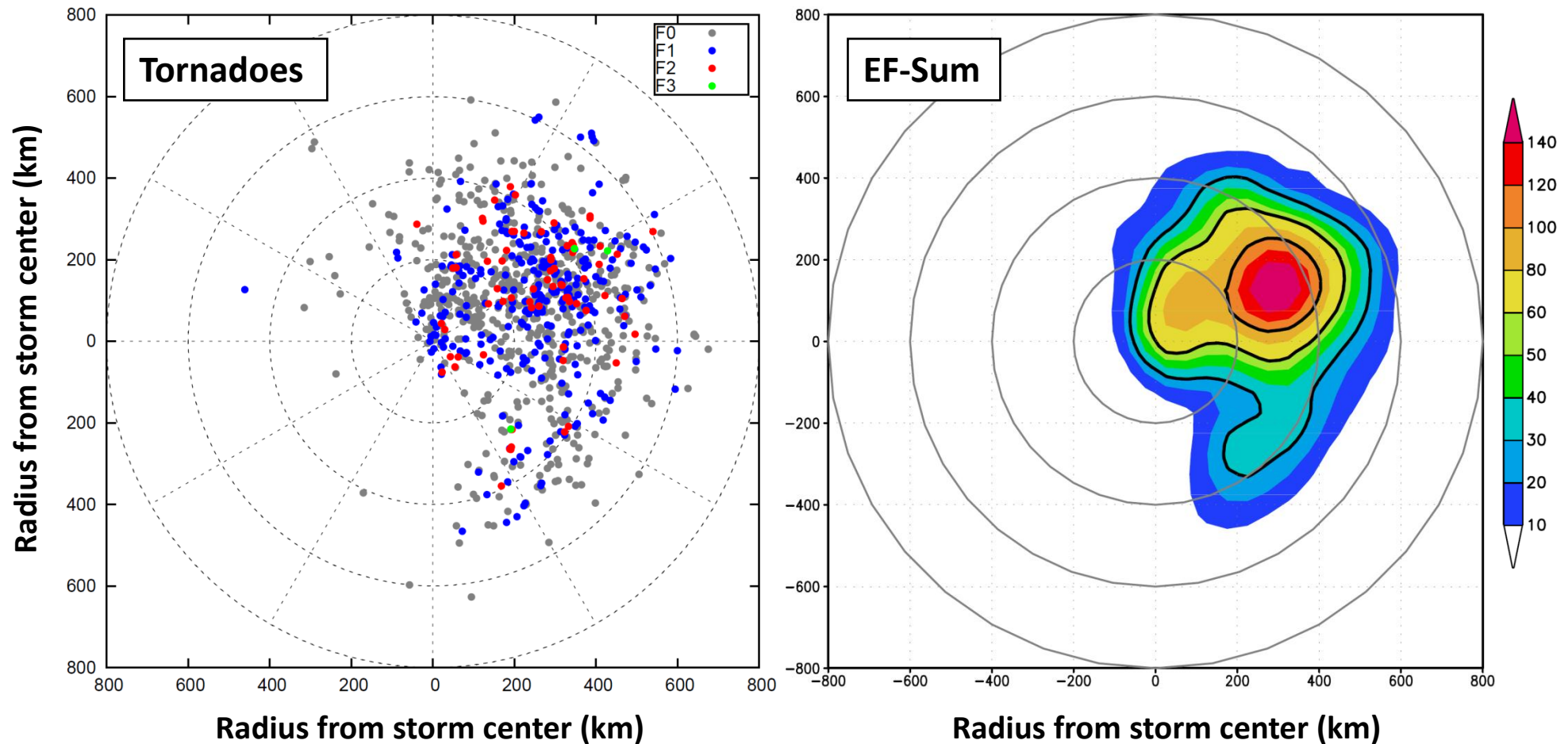
Note: We are not trying to develop a “silver bullet”
We are trying to provide a better “tool” for guidance

Our Approach

1. Complete a climatology of the TC tornado environment
 - All landfalling TCs (1997-2008) – 60 total
 - All tornadoes within 750 km of TC center – 958 total
 - All rawinsondes within 800 km of TC center – 5601 total
 - Compute a wide array of stability, shear, and composite indices (e.g., CAPE, LCL, Shear, CRH, SCP, STP) for each rawinsonde
 - Construct composite mean maps of each parameter using a one-pass Cressman filter with a 100 km radius of influence on a 50×50 km grid
2. Identify significant differences between TC tornado proximity soundings and non-proximity soundings
3. Develop an effective TC Tornado Parameter (TCTP)

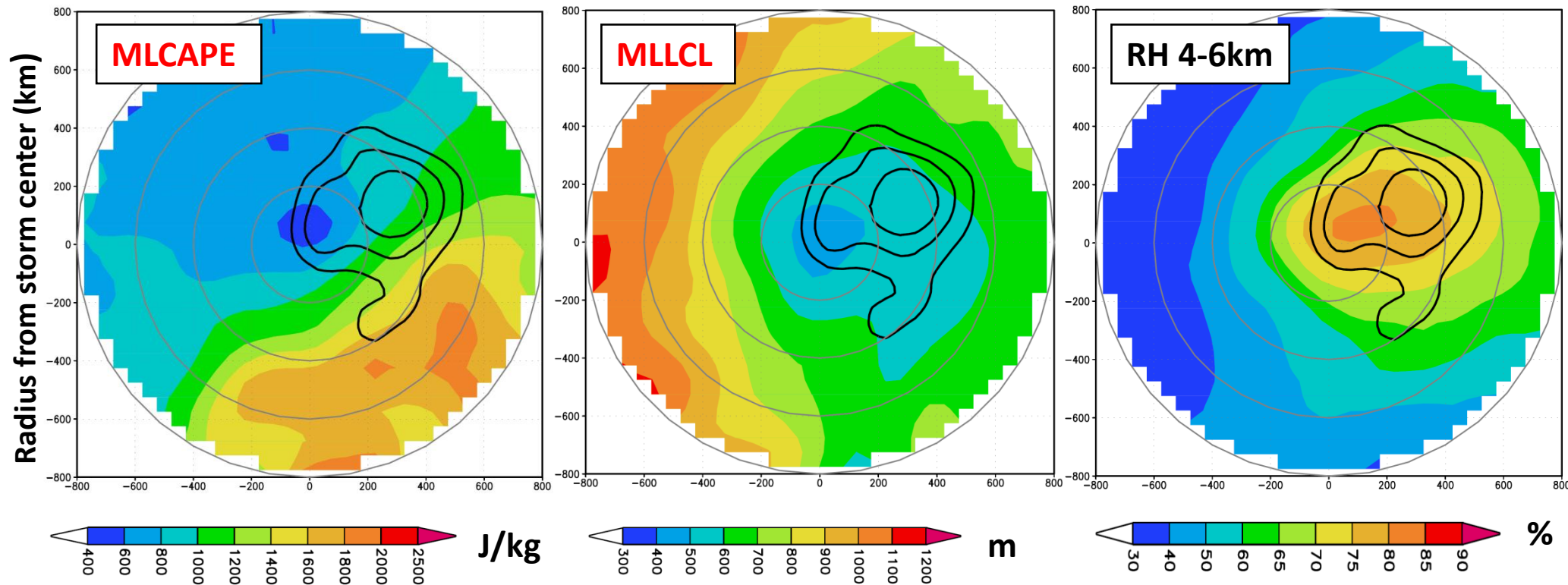
Results – TC Tornado Climatology

Earth-Relative from TC



Results – TC Environment Climatology

Stability / Moisture



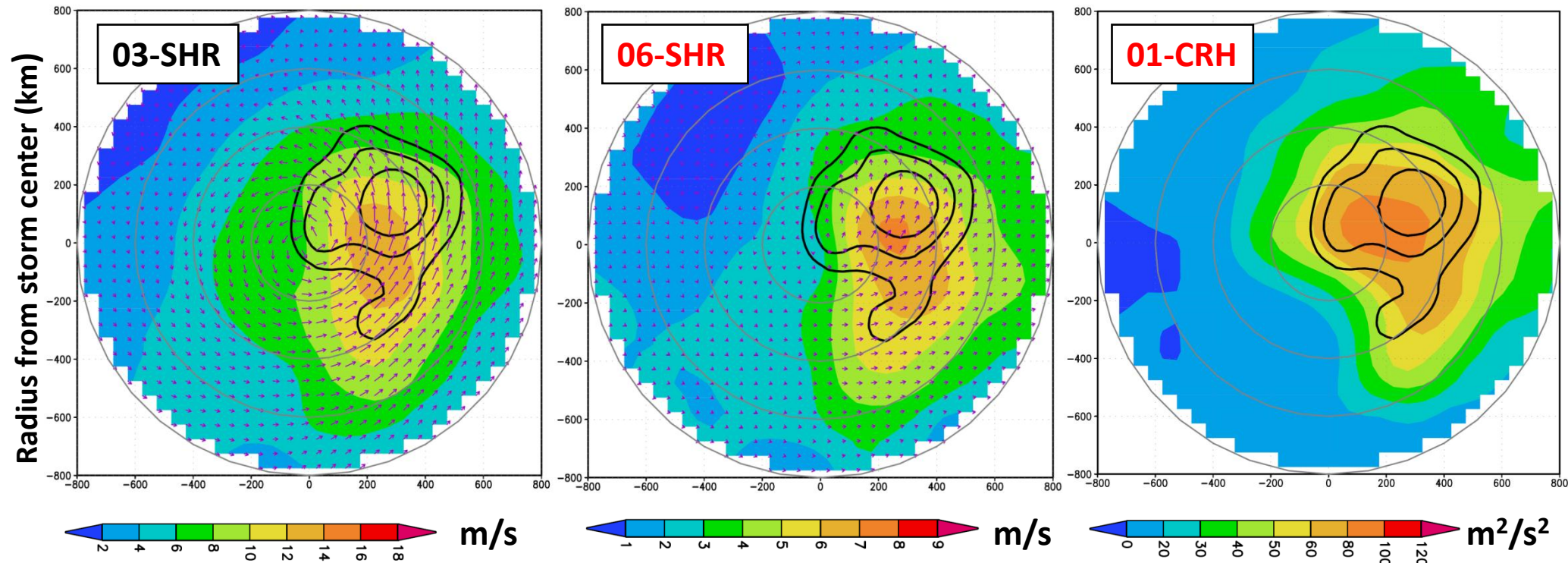
- Non-zero CAPE
- Mean ~ 900 J/kg
- Along thermal boundary

- Low LCL (< 600 m)
- Spatial pattern consistent

- High mid-level relative humidity (>70%)
- Limited evidence for dry air intrusions

Results – TC Environment Climatology

Shear / Helicity



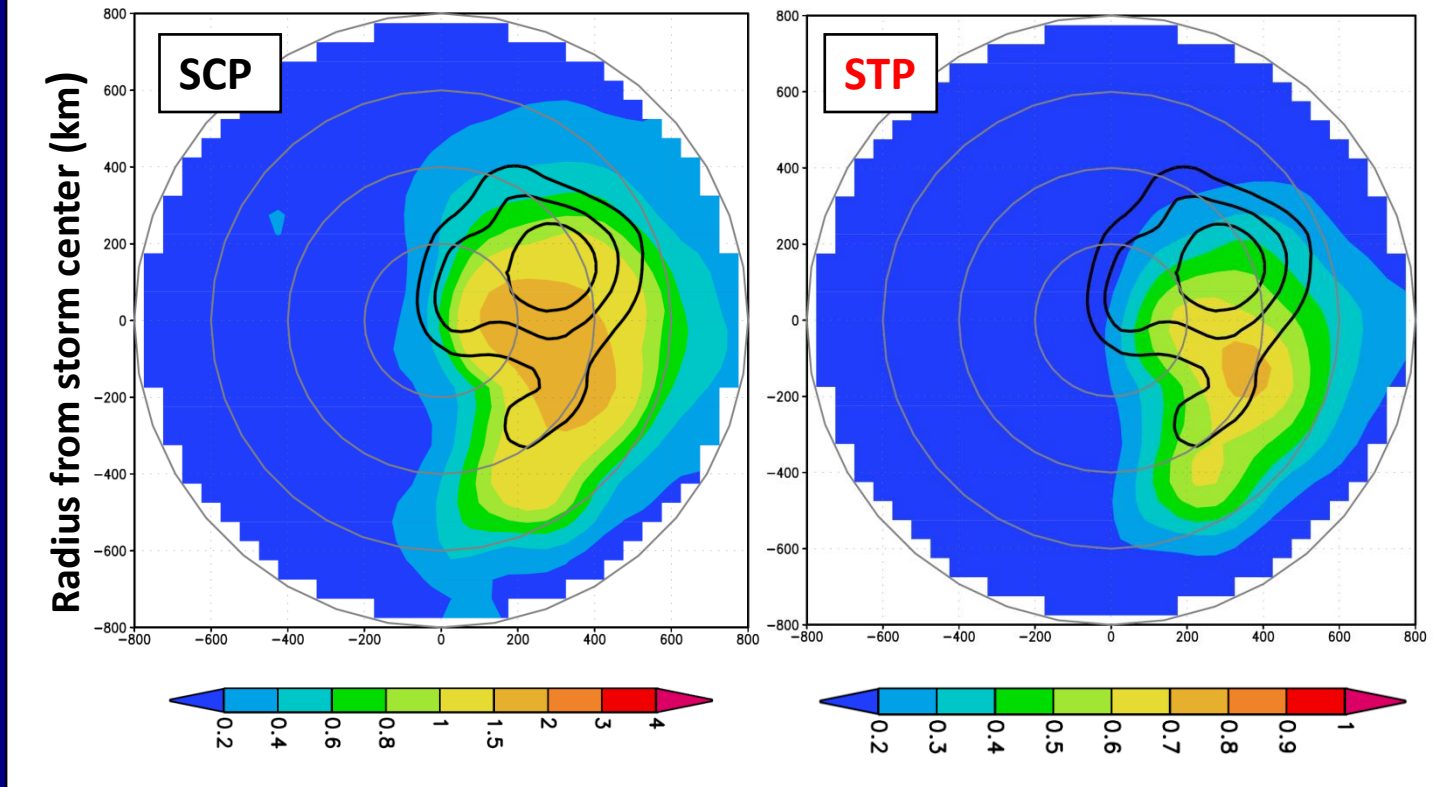
- Low-level shear max (>10 m/s) upstream from TOR max
- “Radial shear” max with TOR max

- Mid-level shear max (>5 m/s) upstream from TOR max
- “Radial shear” max with TOR max

- Moderate low-level CRH (>50 m^2/s^2) with TOR max
- Spatial pattern consistent

Results – TC Environment Climatology

Composite



- Max (>1.0) upstream from TOR max
- Spatial pattern consistent

- Max (>0.5) upstream from TOR max
- Spatial pattern consistent

Our Approach

1. Complete a climatology of the TC tornado environment
2. Identify significant differences between TC tornado proximity soundings and non-proximity soundings

Proximity Sounding

- Launched within 185 km and 3 hours of at least one reported TOR
- Must exhibit non-zero MLCAPE (i.e., warm side of a boundary)
- 184 total

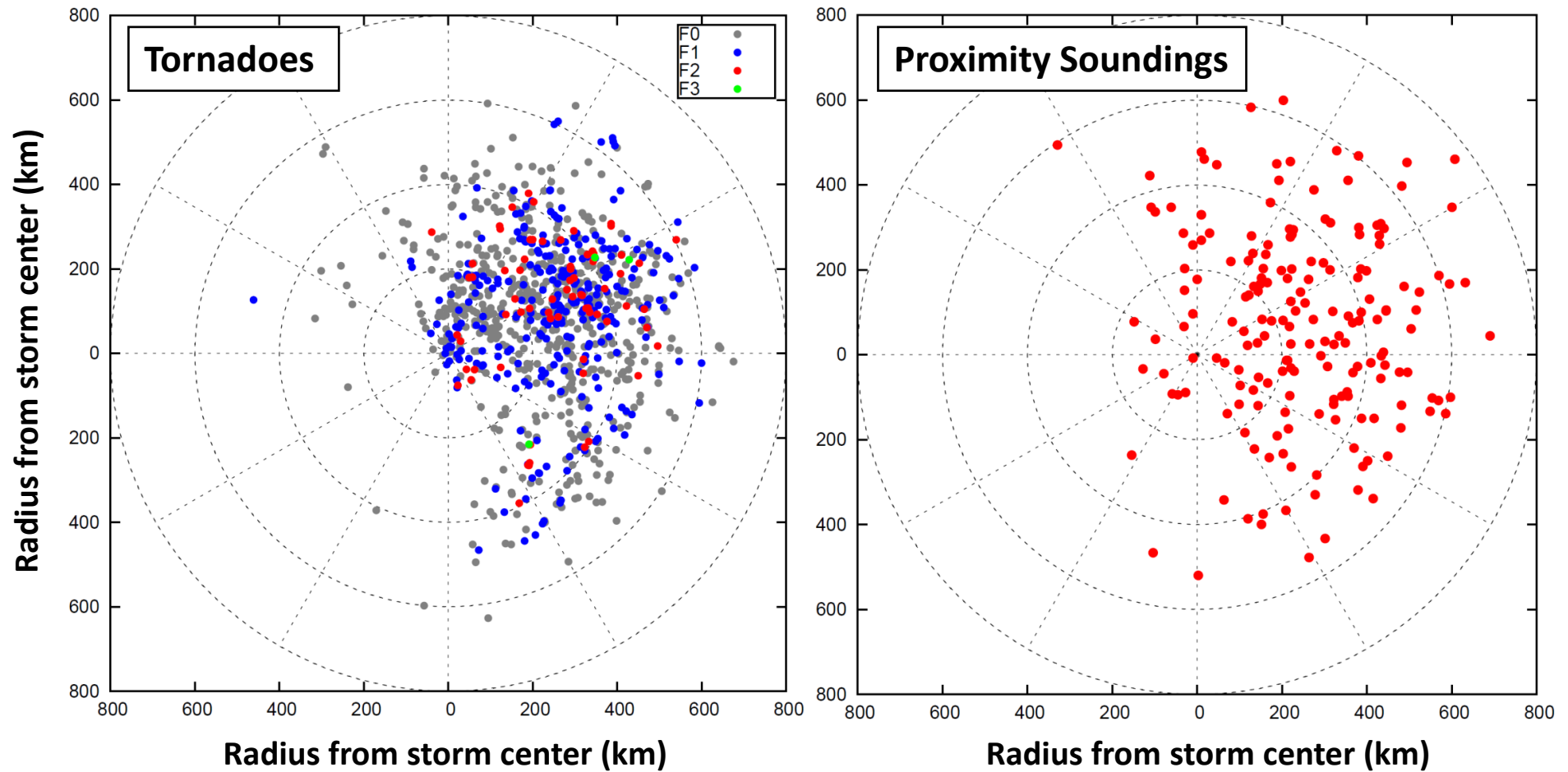
Non-Proximity Sounding

- No TOR reported nearby
- Must exhibit non-zero MLCAPE
- 3956 total

3. Develop an effective TC Tornado Parameter (TCTP)

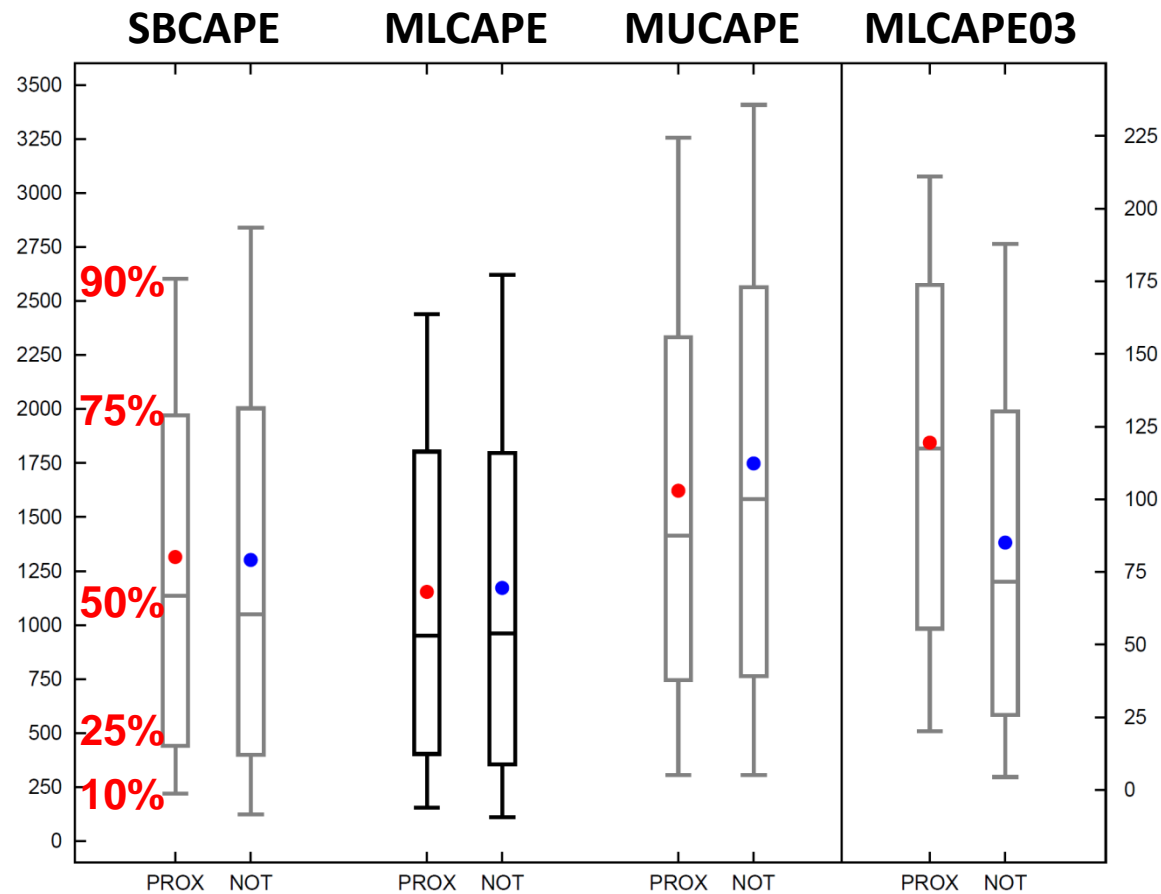
Results – Proximity Soundings

Earth-Relative from TC



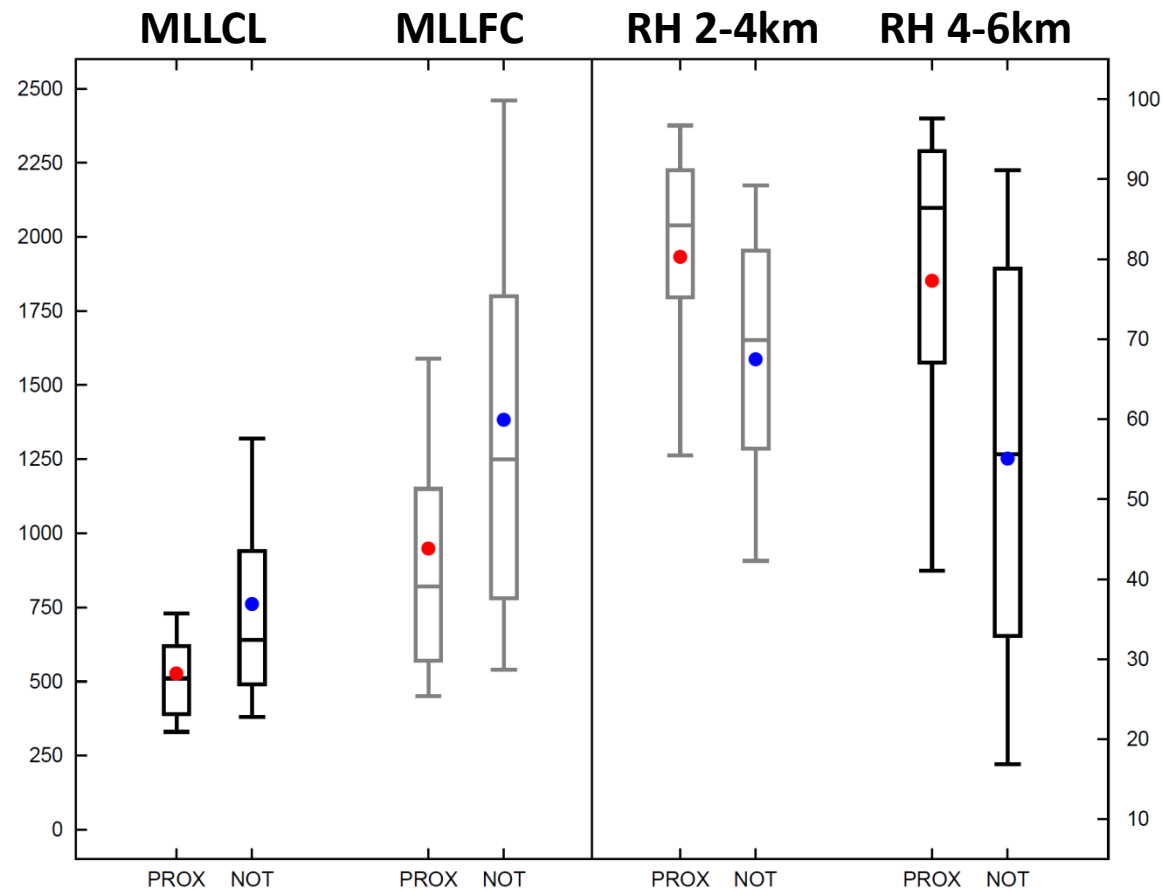
Results – Proximity Soundings

Box-Whisker Comparisons



Results – Proximity Soundings

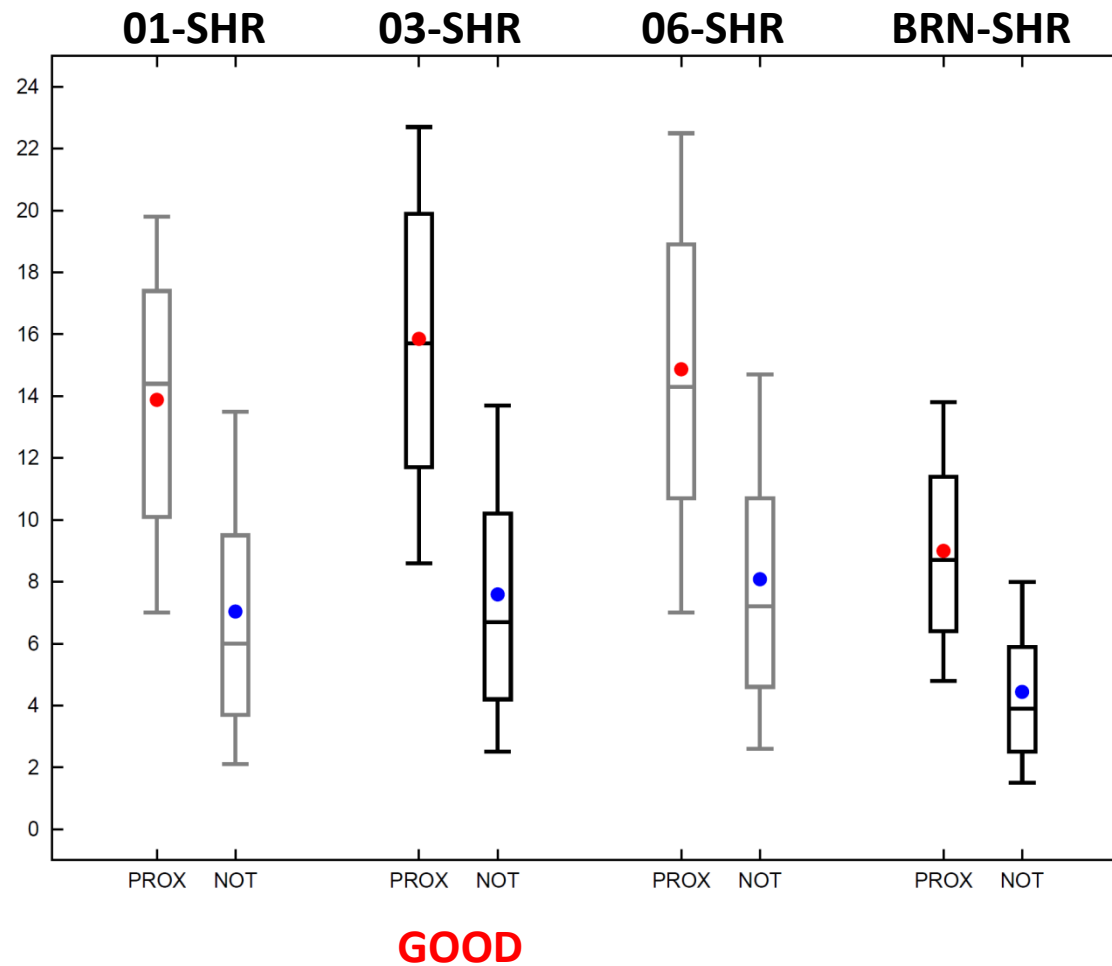
Box-Whisker Comparisons



GOOD

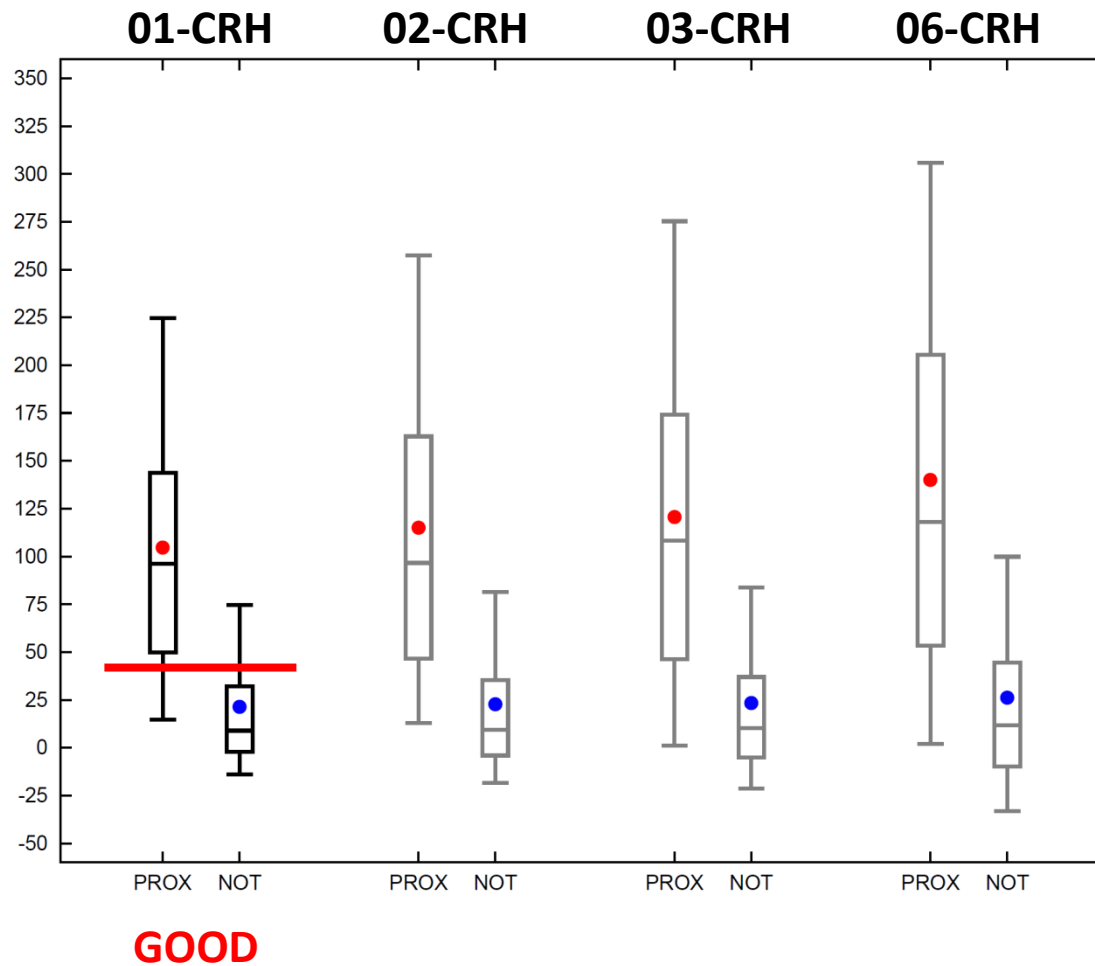
Results – Proximity Soundings

Box-Whisker Comparisons



Results – Proximity Soundings

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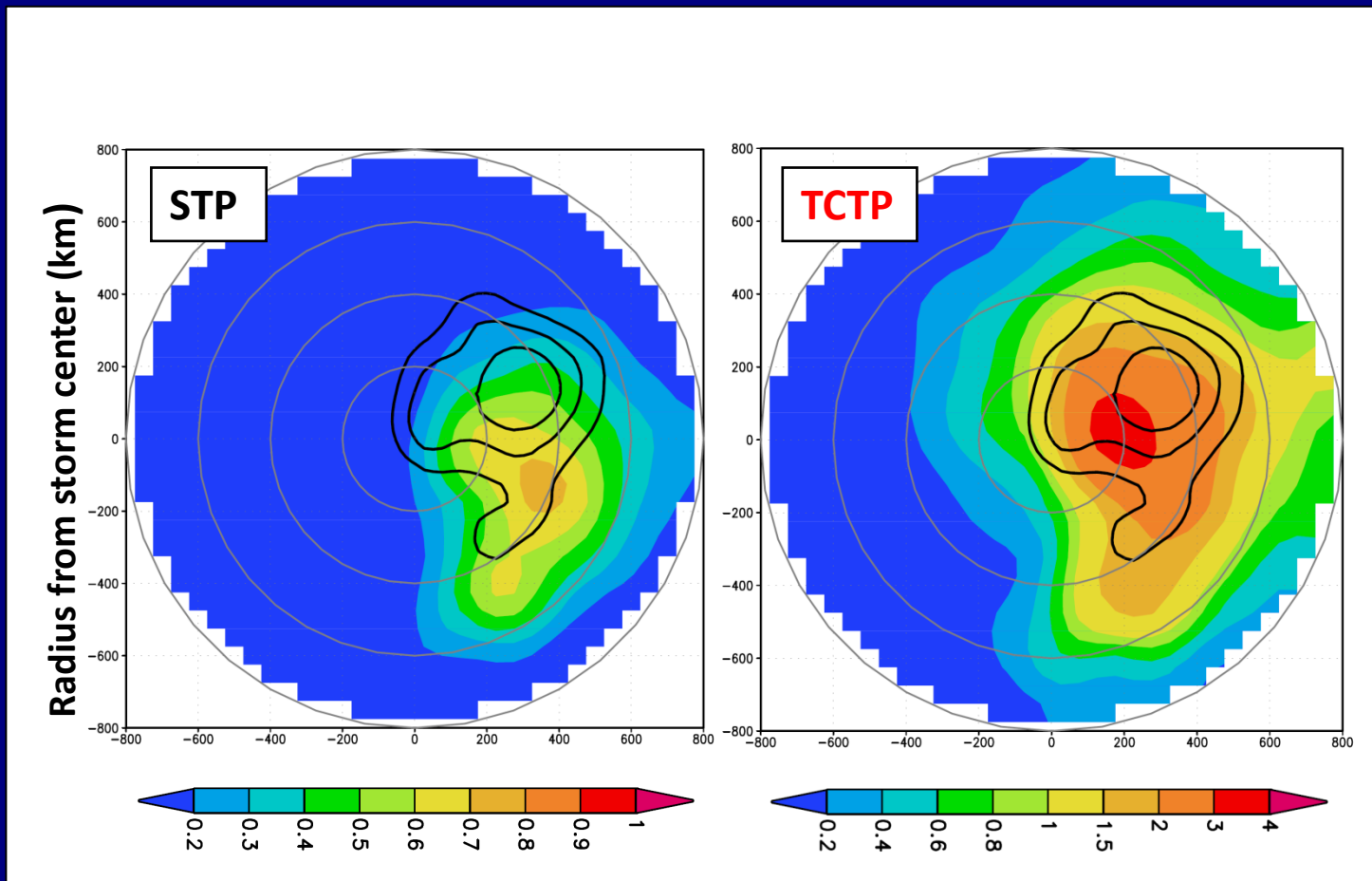
Our Approach

1. Complete a climatology of the TC tornado environment
2. Identify significant differences between TC tornado proximity soundings and non-proximity soundings
3. Develop an effective TC Tornado Parameter (TCTP)
 - Following methods in Thompson et al. (2003)
 - Single normalized non-dimensional parameter
 - Tornadoes \rightarrow TCTP > 1.0
 - Sounding must have non-zero MLCAPE

$$TCTP = \left(\frac{01CRH}{40 m^2 s^2} \right) \times \left(\frac{03SHR}{12 m s^{-1}} \right) \times \left(\frac{2000 - MLLCL}{1400 m} \right)$$

$$STP = \left(\frac{MLCAPE}{1000 J kg^{-1}} \right) \times \left(\frac{01CRH}{100 m^2 s^2} \right) \times \left(\frac{06SHR}{20 m s^{-1}} \right) \times \left(\frac{2000 - MLLCL}{1500 m} \right)$$

Results – TCTP Performance

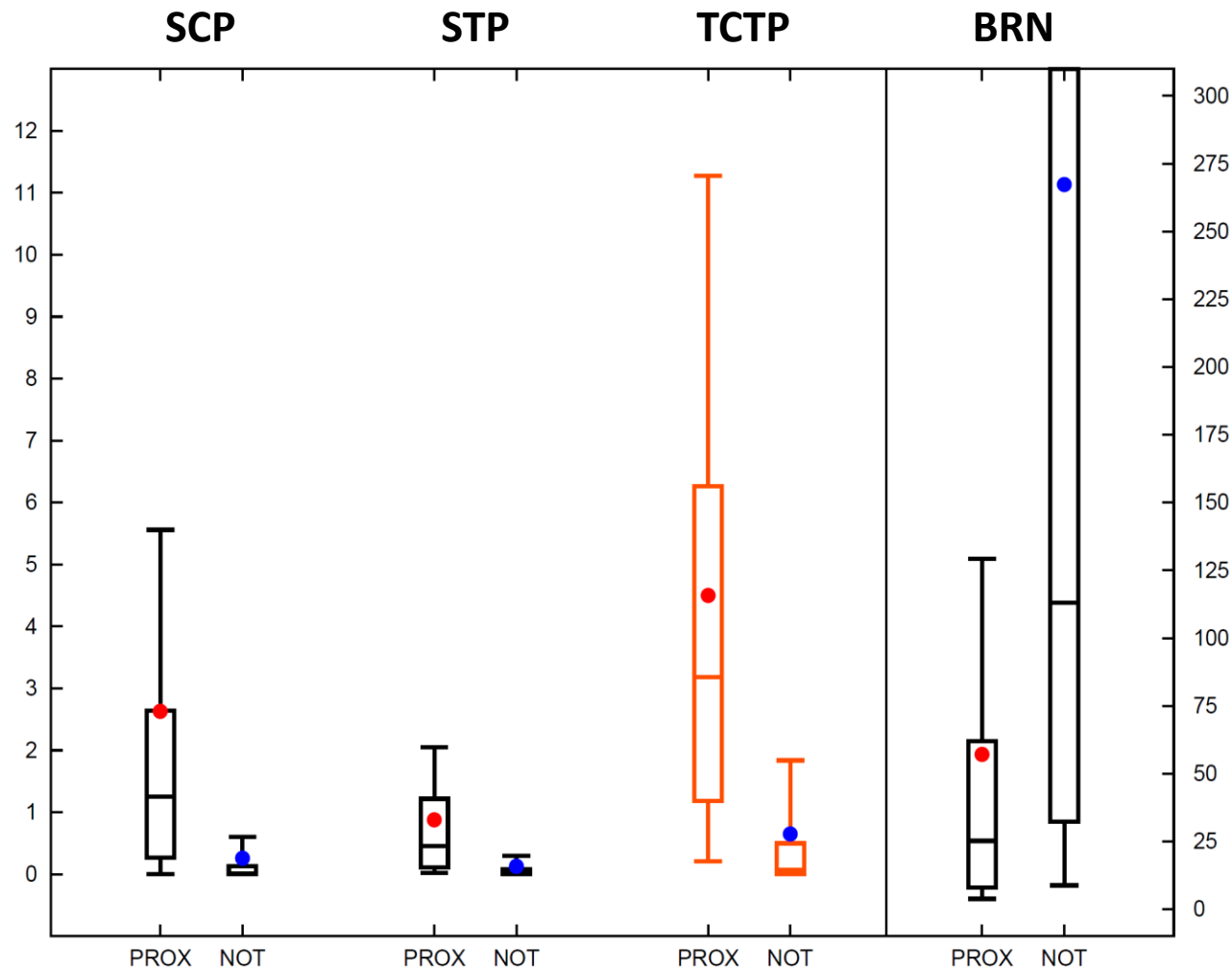


- Max (>0.5) upstream from TOR max
- Spatial pattern consistent

- Max (>1.0) more collocated with all TOR and TOR max
- Spatial pattern consistent

Results – TCTP Performance

Box-Whisker Comparisons



Summary and Future Work

1. Developed a composite sounding parameter which more effectively identifies “threat corridors” for *miniature* supercells and *weak tornadoes* within the *TC environment*

$$TCTP = \left(\frac{01CRH}{40 m^2 s^2} \right) \times \left(\frac{03SHR}{12 ms^{-1}} \right) \times \left(\frac{2000 - MLLCL}{1400 m} \right)$$

2. Complete comprehensive statistical assessment of TCTP using 2×2 contingency tables and associated metrics
3. Explore additional formulations of the TCTP within the context of contingency table analysis
4. Assess TCTP performance using independent dataset from the 2009-2012 landfalling TC cases

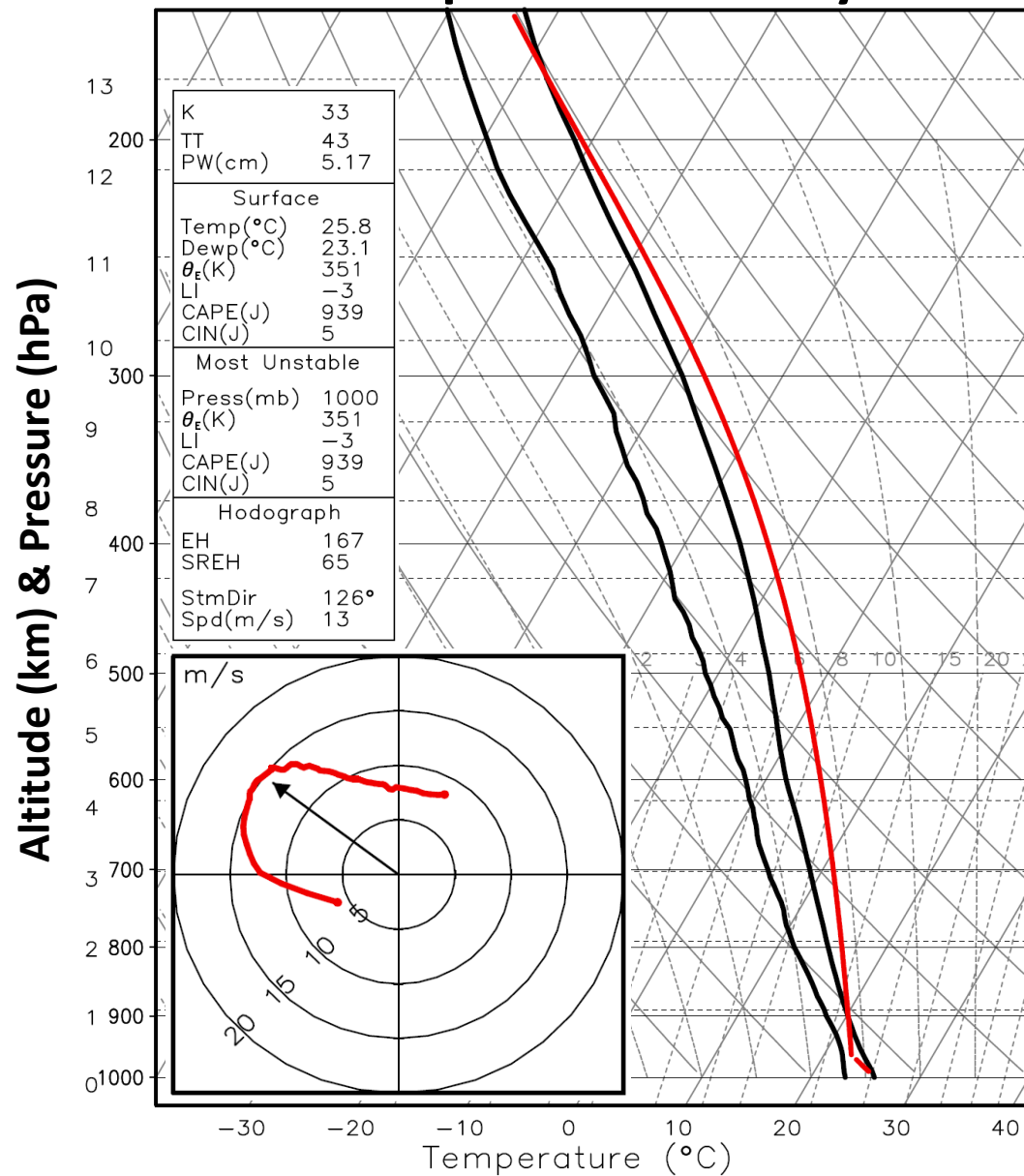
A satellite image of a hurricane over the Atlantic Ocean. The hurricane has a well-defined eye and a dense, swirling cloud structure. The surrounding ocean is a deep blue, and the landmasses of North and South America are visible at the top and bottom edges of the frame.

Thank You

Questions?

Results – Proximity Soundings

Composite Proximity



Composite Non-Proximity

